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Microstructure and initial permeability of Cd-substituted Li-Ni ferrites

C M Kanamadi, R G Kharabe[1], R B Pujar and B K Chougule*

Ferrite Materials Research Laboratory, Department of Physics,
Shivaji University, Kolhapur-416 004, Maharashtra, India
[1] K. L. E. Society's G. I. Bagewadi College, Nipani,
Belgaum-591 237, Maharashtra, India

E-mail: bkchougule@yahoo.com

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Abstract : The microstructure and initial permeability of Cd-substituted Li-Ni ferrites having the general formula $Li_{0.5}Ni_{0.75-x/2}Cd_{x/2}Fe_2O_4$ (where $x = 0, 0.1, 0.3, 0.5, 0.7$ and 0.9), have been reported. The ferrite samples were prepared by standard double sintering ceramic technique and characterized by X-ray diffraction. The lattice parameter (a) increases with increase in Cd content. The SEM studies show that the average grain diameter increases as the content of cadmium increases. The initial permeability (μ_i) increases as Cd content increase. It is observed that μ_i increases gradually with temperature and then it drops near Curie temperature. The Curie temperature of the samples decreases with increase in content of cadmium due to reduction in *A-B* interaction. The variation of initial permeability with frequency shows that μ_i remains invariant with frequency for all samples except with $x = 0.9$ in which it starts increasing beyond 1 MHz of applied frequency.

Keywords : Microstructure, Li-Ni ferrites, initial permeability

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1. Introduction

Lithium ferrites have attracted considerable attention because of the squareness of Hysteresis loop coupled with superior high temperature performance due to their high Curie temperatures [1]. They also have high resistivity, low line width and wide range of saturation magnetization and hence replace Ni-Zn, Mn-Zn ferrites and rare earth garnets in microwave technology [2]. Many investigators have carried out work on lithium ferrites containing various cations such as Cd, Zn, Ni, Mg *etc.* [3-6]. However, no reports have been found so far in the literature about Cd-substituted Li-Ni ferrites. Therefore, in the present communication, we report on the microstructure and initial permeability of Cd-substituted Li-Ni ferrites.

2. Experimental

Cd-substituted Li-Ni ferrites having the general formula $Li_{0.5}Ni_{0.75-x/2}Cd_{x/2}Fe_2O_4$ (where $x = 0, 0.1, 0.3, 0.5, 0.7$ and 0.9) were prepared by standard double sintering technique using high purity oxides. The pre-sintering of the samples was carried out at 600°C for 12 h and final sintering at 1000°C for 24 h. The pellets (1 cm diameter, and 0.5 cm thickness) and torrids (1.5 cm OD, 1 cm ID) pressed at 8 ton/cm^2 were used for the measurement of magnetization, scanning electron microscopy and initial permeability respectively. The single phase formation of the ferrites was confirmed by X-ray diffraction (XRD) patterns obtained by using PHILIPS PW-1710 diffractometer with Cu Kα radiation [λ = 1.5418 Å]. The scanning electron micrographs (SEM) were taken using Cambridge Stereo scan, 250 MK II model. The magnetization measurements were carried out using a high field Hysteresis loop tracer operating at constant magnetic field of 3 kOe. The variation of initial permeability with temperature was measured using LCR-Q meter (Aplab-4912) at a fixed frequency of 1 kHz and its frequency variation with LCR meter (Model -4192A) at room temperature on torroidal samples.

3. Results and discussion

The variation of lattice parameter a with Cd content is shown in Figure 1. The increase in a with Cd content is due to the fact that the radius of Cd^{2+} (0.97Å) ions is larger than the radii of Fe^{3+}

* Corresponding Author

(0.65 Å), Ni^{2+} (0.74Å) and Li^{1+} (0.71Å) ions. The Cd^{2+} ions successively replace the Fe^{3+} ions on the *A*-site. This results in an increase of lattice parameter with cadmium content indicates that the present system obeys Vegard's law. A similar type of variation is observed in Li-Cd [7] and Li-Ni [5] ferrites.

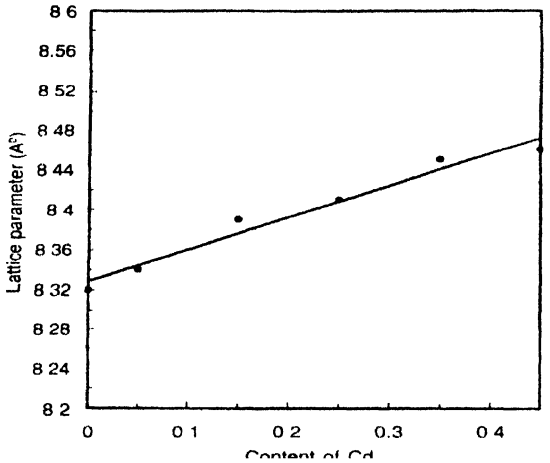

Figure 1. Variation of lattice parameter with content of cadmium.

The SEM micrographs of the samples are shown in Figure 2. The SEM micrographs indicate that all the samples show fine grains with exaggerated grain growth observed in ome samples. The segregation of impurity phases is not observed. The average grain diameter *dm* was calculated by line intercept method. The variation of average grain diameter with Cd content is shown in Figure 3. The average grain diameter increases with Cd content, which is attributed to the diffusion phenomenon involving Cd, oxygen vacancies and less porosity, which hampers the grain growth. The increase in grain diameter with Cd content can also be attributed to smaller solid solubility of nickel in the samples. Sagare [8] has observed increase in grain growth with Cd content in Li-Cd ferrites.

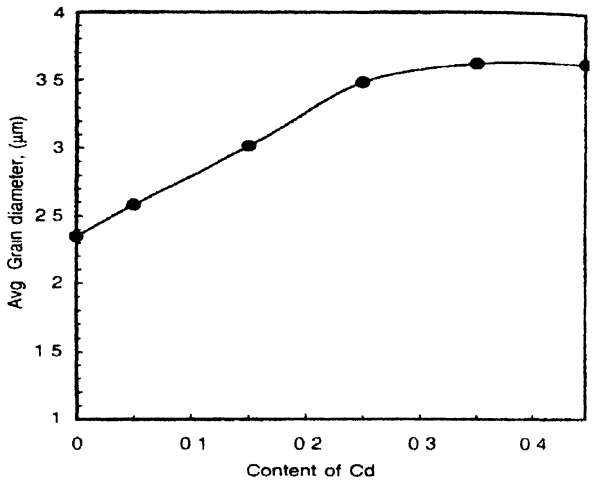

Figure 3. Variation of average grain diameter with cadmium content

The compositional variation of initial permeability at room temperature is shown in Figure 4. The initial permeability increases as content of cadmium increases.

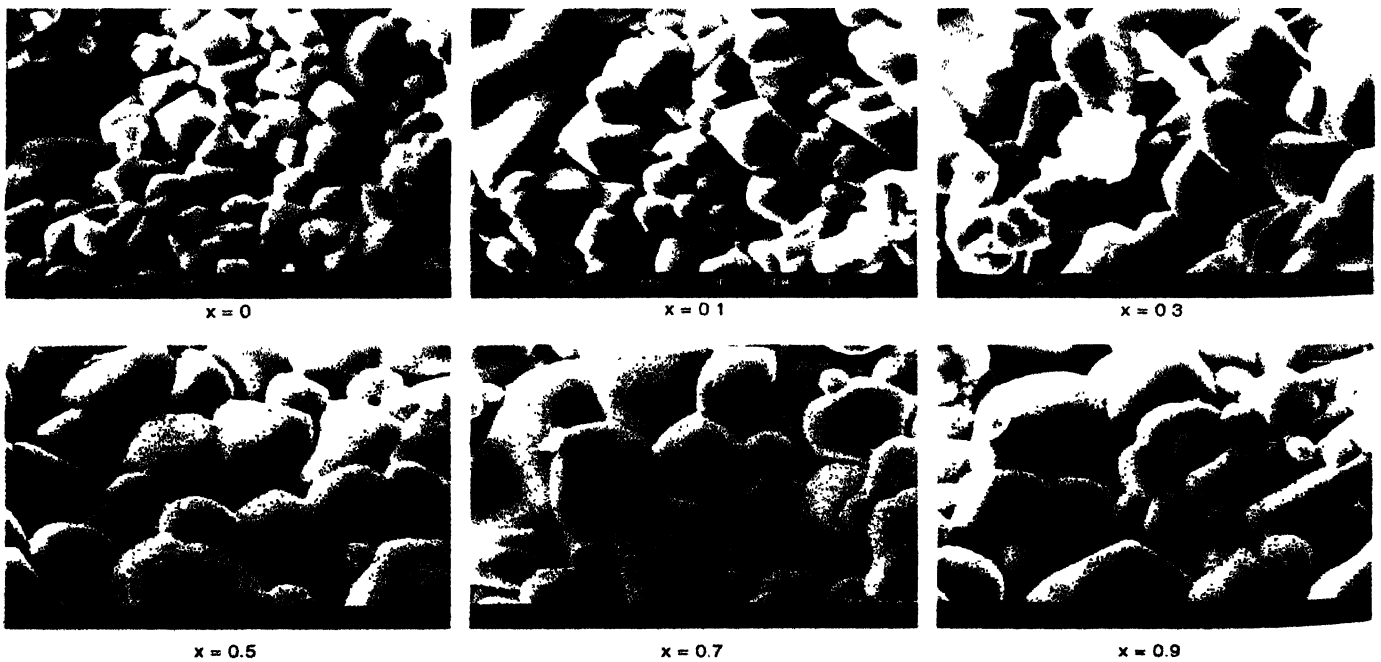

Figure 2. SEM Micrographs of $Li_{0.5}$ $Ni_{0.75-x/2}$ $Cd_{x/2}$ Fe_2O_4 ferrite system for x = 0, 0.1, 0.3, 0.5, 0.7 and 0.9.

The compositional variation of μ_i can be explained on the basis of Globus model [9]. According to this model, μ_i is given by

$$\mu_i = M_s^2 dm / K_1, \quad (1)$$

where M_s is saturation magnetization, dm the average grain diameter and K_1 the magneto crystalline anisotropy constant.

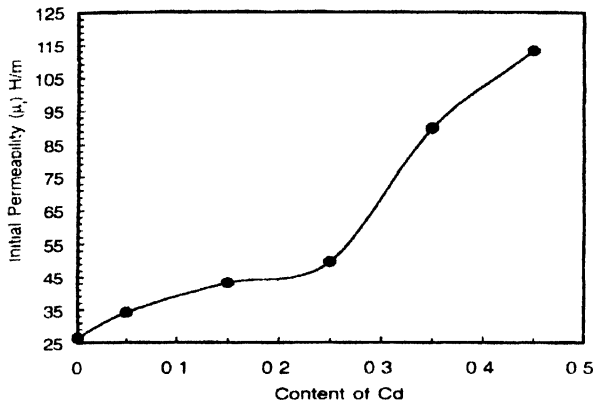

Figure 4. Variation of initial permeability with cadmium content

In the present case, the saturation magnetization shows an increasing trend with CD content up to $x = 0.5$. The grain size has also increasing tendency. The increase in initial permeability is thus expected. Such behaviour is also observed in Li-Cd ferrites reported by Bellad and Chougule [10].

Figure 5 shows the variation of initial permeability with temperature. It is observed that μ_i increases gradually and then it drops to zero near Curie temperature. The sharp decreases near Curie temperature suggest single phase formation of the ferrites.

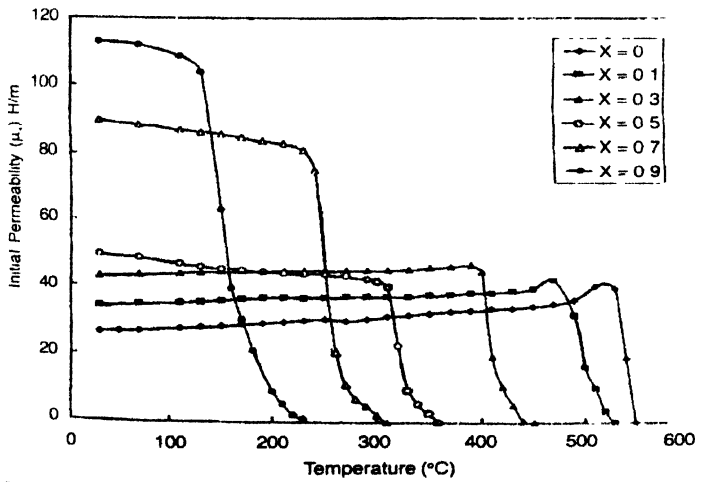

Figure 5. Variation of initial permeability with temperature.

The variation of μ_i with temperature can be explained as follows :

The anisotropy constant and saturation magnetization usually decrease with increase in temperature due to thermal agitation, which disturb the alignment of magnetic moments. But, the decrease of anisotropy with temperature is much faster than the decrease of Ms. When the anisotropy constant reaches zero, μ_i attains its maximum value and then it drops to zero. Similar variation of initial permeability with temperature is reported by Shaikh *et al* [11] in Li-Mg-Zn ferrites.

The variation of Curie temperature as a function of Cd content is shown in Figure 6. It can be observed from the figure that as the content of Cd increases, the Curie temperature decreases. This is expected because the magnetic dilution of

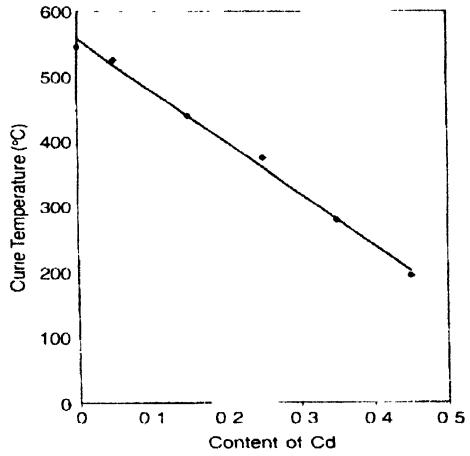

Figure 6. Variation of Curie temperature with cadmium content

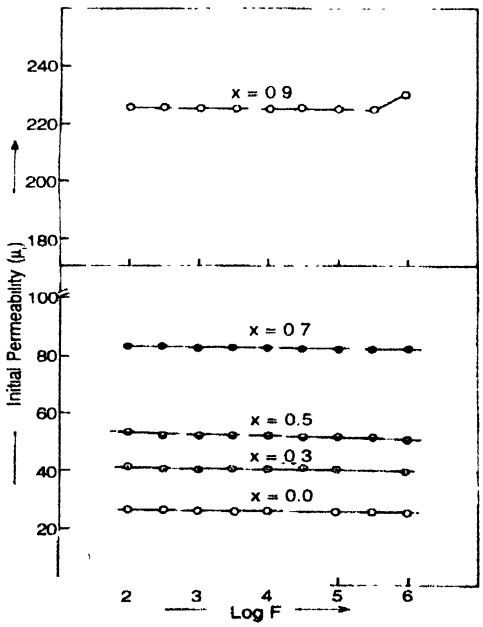

Figure 7. Variation of initial permeability with frequency.

the samples weakens the $A-B$ interaction which decreases the T_c value. Similar trend in T_c value with Cd content is observed in case of Li-Cd ferrites studied by Bellad and Chougule [10].

The variation of initial permeability with frequency is shown in Figure 7. It is observed that μ_i remains invariant with frequency for all samples. Bhosale *et al* [12] have studied Gd^{3+} substituted Mg-Cd ferrites in the frequency range 1 kHz – 1 MHz and observed just an approach of resonance maximum at 1 MHz.

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